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Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

Developments to improve the throughput and efficiency of Earth System Models

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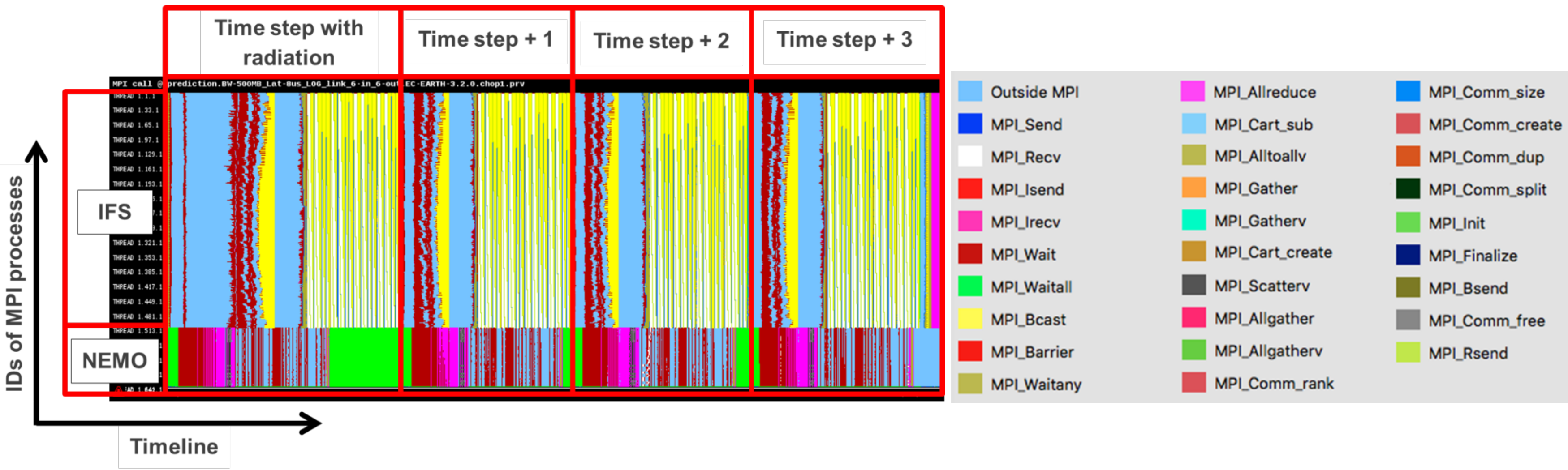
Introduction

- Weather and climate models are **improving the accuracy of their simulations**. As a consequence, **more computational resources** will be needed through a **new generation of supercomputers**
- **Performance analyses** are required to study the computational behavior of Earth System models (ESMs) to **detect bottlenecks**. Then, using state-of-the-art methodologies, **proper optimizations** should be applied to improve the ESMs' **throughput and energy efficiency**.
- In my case, I focus on two ESMs which are related:
  - **EC-Earth** [1] is a **global coupled climate model**, which integrates a number of component models in order to simulate the Earth system. The two main components are **IFS as atmospheric model** and **NEMO as ocean model**, both **coupled using OASIS3-MCT**.
  - OpenIFS [2] is a free, but licensed version of the ECMWF IFS model. IFS (Integrated Forecasting System) is a global data assimilation and forecasting system, which includes the modelling of the atmospheric composition.
- In both models, to achieve a good efficiency is a complex issue, especially in EC-Earth

BSC tools

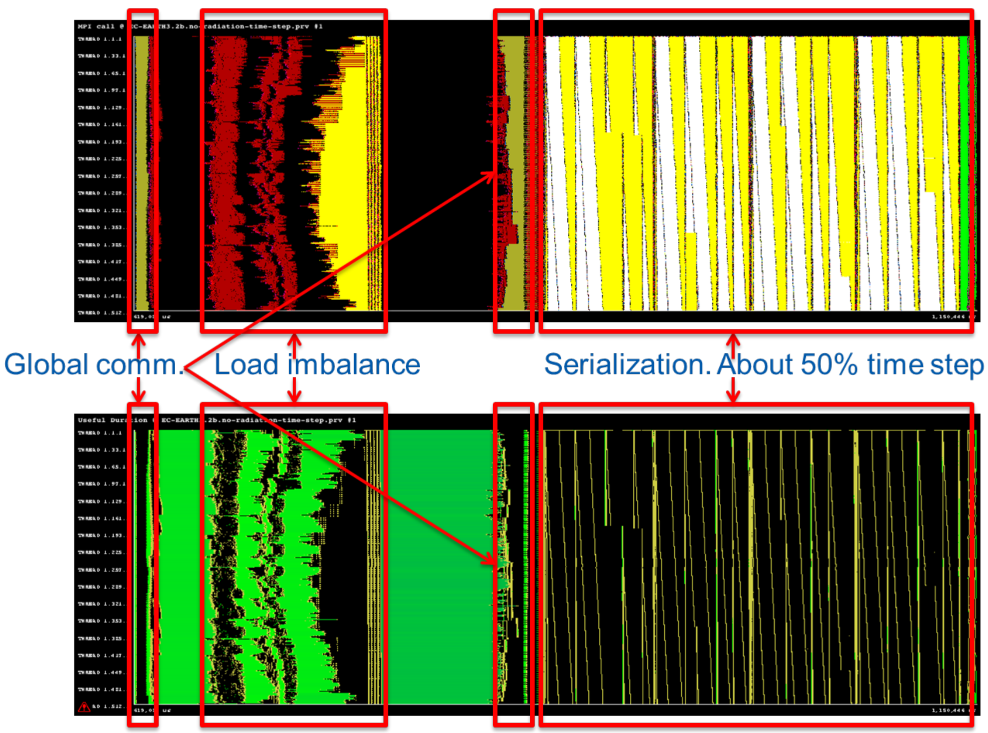
- Performance tools [3] are essential to study the behavior of ESMs:
  - **Extrae**: is a package used to instrument the code. It generates trace-files with hardware counters, MPI messages and other information
  - **Paraver**: is a browser used to analyze both visually and analytically trace-files
  - **Dimemas**: is a simulator based on traces to predict the behavior of message-passing programs on configurable parallel machines
- Below, there is an EC-Earth trace with timeline on the X axis and MPI processes on the Y axis. There are 4 time steps, using 512 processes for IFS and 128 for NEMO. Particularly, one of the IFS time steps executes radiation. This trace shows MPI functions, where each color identifies a type of call.

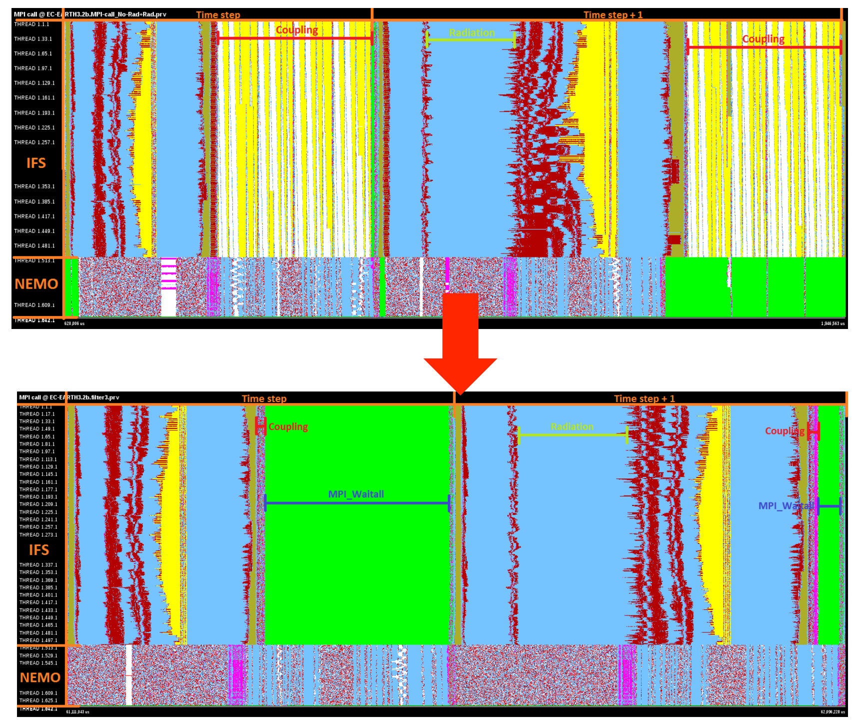


Performance analysis of EC-Earth

We applied the BSC tools to EC-Earth to analyze its computational behavior. We were able to improve the IFS time step significantly:

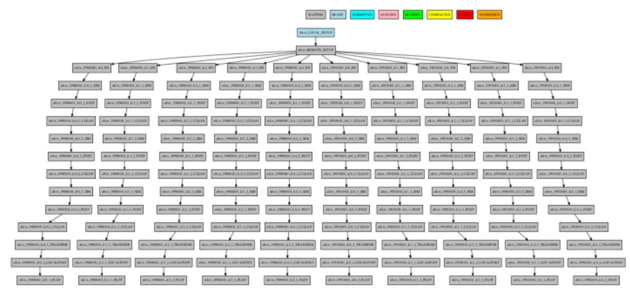
- On the left side (performance analysis) [4][6], there are two traces highlighting the main issues of IFS. The biggest issue is a serialization in the conservative part of the coupler OASIS3-MCT
- On the right side (optimization) [5], the bottom trace shows how the IFS time step is improved after applying an optimization that makes use of the MPI_Allreduce

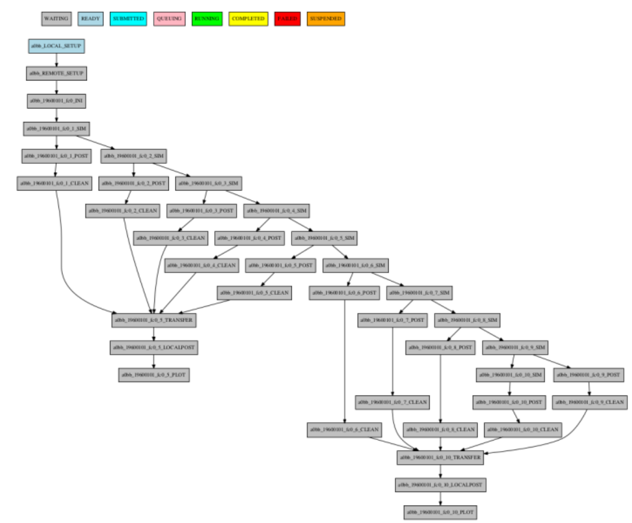




Enhancing throughput in ESM workflows

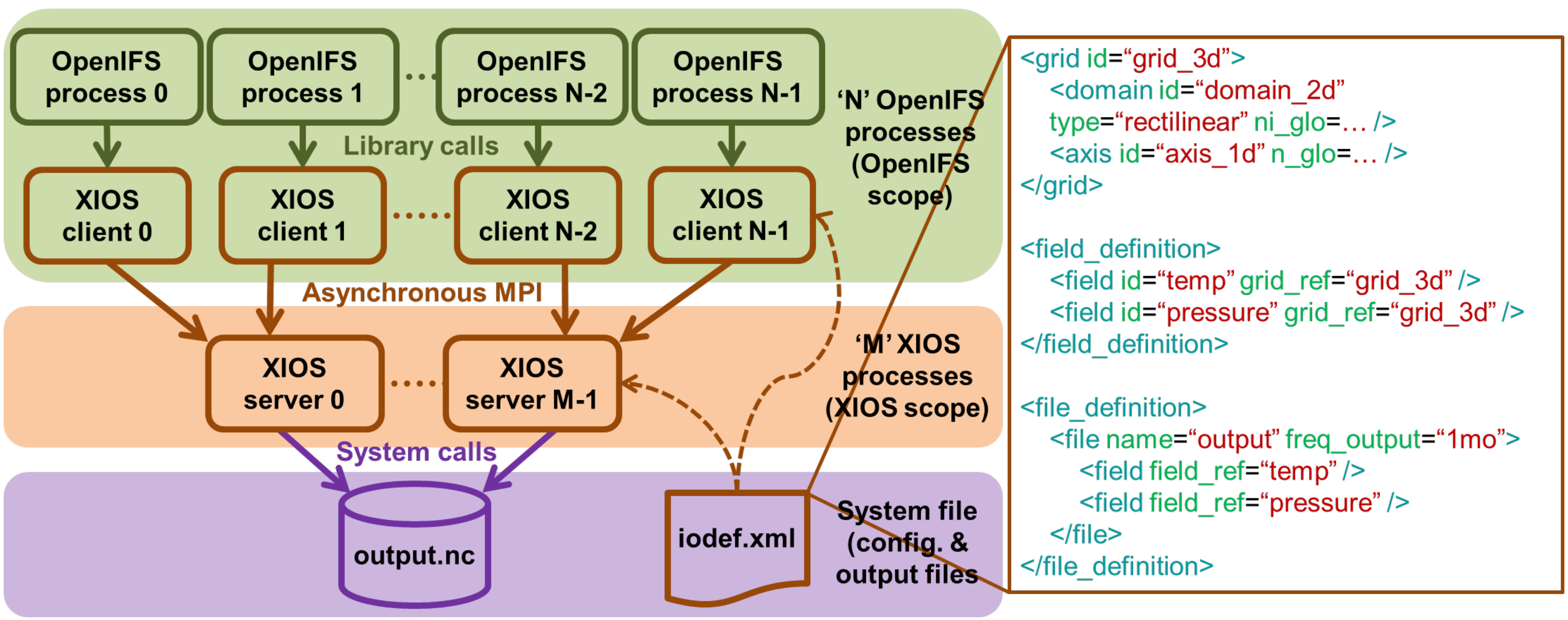
- Some facts:
  - In general, using a few MPI processes has good efficiency
  - Simulations must have a reasonable time-to-solution
  - Workflows usually have enough ready jobs to exploit throughput
  - By exploiting throughput, small jobs with good efficiencies finish before than huge ones with very low efficiencies (having a fixed amount of usable cores at the same time)
  - In some situations, if we have a limited budget of computing hours, it is only possible to finish a simulation using small and efficient jobs
- We should use a tunable trade-off between performance and parallel efficiency
- Implement a scheduler for a workflow manager, such as Autosubmit or Cylc, to maximize the throughput.





OpenIFS integration with XIOS

- This task focuses on the I/O of OpenIFS with a twofold goal:
  - Increase the **functionality of and usability of EC-Earth**, since in a future it will use OpenIFS as the atmospheric component.
  - **Speedup the throughput** (more performance)
- The approach to achieve it is using **XIOS** (XML Input/Output Server) [7]. It is able to decouple the direct writing of a model using several servers communicated through **asynchronous MPI** communications. Thus, the model does not have to wait for the I/O to be done



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Thank you!

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References

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[2] ECMWF. OpenIFS, 2017: https://software.ecmwf.int/wiki/display/OIFS/OpenIFS+Home

[3] Barcelona Supercomputing Center. BSC performance tools, 2016: https://tools.bsc.es/

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[7] IPSL. XIOS, 2017: http://forge.ipsl.jussieu.fr/ioserver/wiki